

What is Claimed:

1. A catheter comprising an elongated tube having an interior defined by a sidewall and having one or more openings, and at least a portion of the catheter spirally formed into a corkscrew pattern to define a corkscrew-patterned portion, wherein at least one of said openings is coincident with the corkscrew-patterned portion.

2. The catheter of claim 1, wherein the one or more openings comprise a plurality of openings in the sidewall.

3. The catheter of claim 2, wherein the corkscrew pattern comprises an outer diameter (d_o) and the at least one of said sidewall openings is positioned facing away from the outer diameter.

4. The catheter of claim 1, wherein the tube has a tube diameter (d_i) in a range of approximately 0.2-0.7 centimeters, and the corkscrew pattern has an outer diameter (d_o) in a range of approximately 1-5 centimeters.

5. The catheter of claim 2, wherein the plurality of sidewall openings are distributed in a helical pattern along the sidewall.

6. The catheter of claim 1 further comprising a septum that divides the interior into at least a first lumen and a second lumen.

7. The catheter of claim 6, wherein the first lumen and the second lumen form a double helix in a portion of the catheter coincident with the one or more openings.

8. The catheter of claim 7, wherein the openings are distributed on the sidewall at an angle of 90° relative to the septum.

9. The catheter of claim 6, wherein the first lumen and the second lumen form a double helix along an entire length of the catheter.

10. The catheter of claim 6, wherein the septum divides the interior into more than two lumens that form a multiple helix.

11. The catheter of claim 10, wherein the more than two lumens form a multiple helix along an entire length of the catheter.

1 12. The catheter of claim 10, wherein the first lumen extends distally
2 further than a distal end of the second lumen.

1 13. The catheter of claim 1, wherein the corkscrew pattern terminates with
2 the catheter pointed in an axial direction.

1 14. The catheter of claim 1, wherein the corkscrew pattern terminates with
2 the catheter pointed circumferentially.

1 15. The catheter of claim 1, wherein the corkscrew pattern terminates with
2 the catheter pointed tangentially.

1 16. The catheter of claim 1, wherein at least a plurality of the one or more
2 openings are radially formed in the sidewall.

1 17. The catheter of claim 1, wherein the catheter has a central axis, and at
2 least a plurality of the one or more openings are formed in the sidewalls at a non-
3 perpendicular angle relative to the central axis.

1 18. The catheter of claim 1, wherein the catheter is a perfusion catheter.

1 19. The catheter of claim 18, wherein the catheter is a hemodialysis
2 catheter.

1 20. The catheter of claim 1, wherein the catheter comprises a flexible
2 polymer.

1 21. The catheter of claim 1, wherein the catheter comprises a thermoplastic
2 elastomer.

1 22. The catheter of claim 1, wherein the catheter comprises a material of
2 construction selected from the group consisting of: polyvinylchloride, polyethylene,
3 polypropylene, polyurethane, nylon, a polyether block amide, metal, carbon fibers, glass
4 fibers, a combination thereof, and a composite thereof.

1 23. The catheter of claim 1, wherein the catheter comprises at least one
2 layer that comprises a braided architecture.

1 24. The catheter of claim 1, wherein the catheter is a single lumen catheter
2 having an open end and a tube diameter(d_i), the corkscrew pattern defines a space comprising
3 an outer diameter (d_o) greater than the tube diameter, and the open end is positioned centrally
4 within the space.

1 25. The catheter of claim 1, wherein the catheter comprises a tunneling
2 catheter.

1 26. A catheter comprising an elongated tube having an interior defined by a
2 sidewall and a septum dividing the interior into at least a first lumen and a second lumen,
3 wherein the first lumen and the second lumen form a double helix at least in a portion of the
4 catheter coincident with one or more openings in the catheter.

1 27. The catheter of claim 26, wherein the first lumen and the second lumen
2 form a double helix along an entire length of the catheter.

1 28. The catheter of claim 26, wherein the septum divides the interior into
2 more than two lumens that form a multiple helix.

1 29. The catheter of claim 28, wherein the more than two lumens form a
2 multiple helix along an entire length of the catheter.

1 30. The catheter of claim 26, wherein the catheter is a perfusion catheter.

1 31. The catheter of claim 26, wherein the catheter is a hemodialysis
2 catheter.

1 32. The catheter of claim 26, wherein the first lumen extends distally
2 further than a distal end of the second lumen.

1 33. The catheter of claim 26, wherein the one or more openings comprises
2 a plurality of openings in the sidewall.

1 34. The catheter of claim 26, wherein the catheter comprises a flexible
2 polymer.

1 35. The catheter of claim 26, wherein the catheter comprises a
2 thermoplastic elastomer.

1 36. The catheter of claim 26, wherein the catheter comprises a material of
2 construction selected from the group consisting of: polyvinylchloride, polyethylene,
3 polypropylene, polyurethane, nylon, a polyether block amide, metal, carbon fibers, glass
4 fibers, a combination thereof, and a composite thereof.

1 37. A multi-lumen catheter having a sidewall and one or more openings,
2 the catheter adapted for minimized obstruction of the one or more openings by a lumen wall
3 in which the catheter is positioned, wherein, in at least in a portion of the catheter coincident
4 with the one or more openings, the catheter:

5 (a) further comprises a twisting septum dividing an interior of the catheter
6 into multiple lumens, the multiple lumens forming a multi-helix;

7 (b) is spirally formed into a corkscrew pattern;

8 (c) is formed into an inwardly spiraling portion having a periphery that
9 defines an open area, the one or more openings positioned facing or within the open area; or

10 (d) a combination of (a) and (b) or (a) and (c).

1 38. A multi-lumen catheter tip having a sidewall and one or more
2 openings, the catheter tip adapted for minimized obstruction of the one or more openings by
3 a lumen wall in which the catheter tip is positioned, wherein the catheter tip:

4 (a) further comprises a twisting septum dividing an interior of the catheter
5 tip into multiple lumens, the multiple lumens forming a multi-helix;

6 (b) is spirally formed into a corkscrew pattern;

7 (c) is formed into an inwardly spiraling portion having a periphery that
8 defines an open area, the one or more openings positioned facing or within the open area; or

9 (d) a combination of (a) and (b) or (a) and (c).

1 39. A method of making a multi-lumen catheter having a body and a
2 catheter tip, the catheter tip comprising a sidewall and one of: a twisting septum dividing an
3 interior of the catheter tip into multiple lumens in a multi-helix, being spirally formed into a
4 corkscrew pattern, or a combination thereof, the method comprising the steps of:

- 5 (a) forming the multi-lumen catheter body;
- 6 (b) molding the catheter tip into the multi-helix, the corkscrew pattern, or
7 both; and
- 8 (c) attaching the catheter body to the catheter tip.

1 40. A method of making a multi-lumen catheter having a body and a
2 catheter tip, the catheter tip comprising a sidewall and one of: a twisting septum dividing an
3 interior of the catheter tip into multiple lumens in a multi-helix, being spirally formed into a
4 corkscrew pattern or an inwardly spiraling portion, or a combination thereof, the method
5 comprising the steps of:

- 6 (a) forming the multi-lumen catheter;
- 7 (b) heating at least the catheter tip to a sufficient temperature at which the
8 catheter tip can be deformed;
- 9 (c) deforming the catheter tip into the multi-helix, the corkscrew pattern,
10 the inwardly spiraling portion, or a combination thereof; and
- 11 (d) cooling the catheter tip.

1 41. A method of making a multi-lumen catheter having a sidewall and a
2 twisting septum dividing an interior of the catheter into multiple lumens in a multi-helix, the
3 method comprising extruding the catheter using an extrusion tooling insert that rotates to
4 form the twisting septum.

1 42. A method of making a multi-lumen catheter having a sidewall and a
2 twisting septum dividing an interior of the catheter into multiple lumens in a multi-helix, the
3 method comprising extruding the catheter and septum with no twist in the septum and then
4 twisting the catheter as it exits the extruder.

1 43. A method of providing hemodialysis, the method comprising the steps
2 of:

- 3 (a) introducing a multi-lumen catheter into a body lumen having a wall,
4 the catheter comprising a body and a catheter tip and defining at least a first lumen and a

5 second lumen, wherein the catheter tip comprises a sidewall and either: further comprises a
6 twisting septum dividing an interior of the catheter tip into at least the first lumen and the
7 second lumen in a multiple-helix; is spirally formed into a corkscrew pattern or an inwardly
8 spiraling pattern; or a combination thereof;

9 (b) drawing blood from the body lumen through one or more openings into
10 the first catheter lumen, wherein the multiple-helix, corkscrew pattern, inwardly spiraling
11 pattern, or combination thereof minimizes occlusion of the one or more openings by the body
12 lumen wall;

13 (c) cleansing the blood by hemodialysis; and

14 (d) returning the blood through the second catheter lumen into the body
15 lumen.

1 44. The method of claim 43, wherein step (a) comprises deploying the
2 catheter in the body lumen of a patient having a heart with a right atrium such that the a
3 distal end of the catheter is located in or adjacent to the right atrium of the patient's heart.

1 45. The method of claim 44, wherein the catheter tip comprises a
2 corkscrew pattern and the second lumen extends distally further than a distal end of the first
3 lumen and is pointed in a direction toward the right atrium, wherein step (d) comprises
4 returning the blood in a stream directed toward the right atrium.

1 46. A catheter comprising an elongated tube having one or more openings,
2 at least a portion of the catheter coincident with the one or more openings formed into an
3 inwardly spiraling portion having a periphery that defines an open area, the one or more
4 openings positioned within the open area or facing the open area.

1 47. The catheter of claim 46, wherein the catheter comprises an open end,
2 wherein the open end is positioned within the open area.

1 48. The catheter of claim 47, wherein the catheter comprises a single
2 lumen catheter.

1 49. The catheter of claim 46, wherein the catheter comprises a sidewall and
2 a plurality of openings in the sidewall wherein the plurality of sidewall openings are
3 positioned facing the open area.

1 50. A catheter for deployment in a lumen having a wall, the catheter
2 comprising an elongated tube comprising a catheter tip, one or more openings in the catheter
3 tip, and a deformation in the catheter tip for preventing the one or more openings from
4 contacting the lumen wall.

1 51. The catheter of claim 50, wherein the deformation comprises a
2 corkscrew pattern.

1 52. The catheter of claim 50, wherein the deformation comprises an
2 inwardly spiraling portion.

1 53. The catheter of claim 52, wherein the catheter comprises an uncurled
2 portion proximal of the inwardly spiraling portion having a lower surface that lies within a
3 first plane tangential to the lower surface, the inwardly spiraling portion curling away from
4 the first plane and lying at least partially within a second plane perpendicular to the first
5 plane.

1 54. The catheter of claim 53, wherein the inwardly spiraling portion
2 comprises a curl of greater than 360 degrees.

1 55. The catheter of claim 53, wherein the inwardly spiraling portion
2 comprises a curl of approximately 360 degrees.

1 56. The catheter of claim 53, wherein the inwardly spiraling portion
2 comprises a curl of less than 360 degrees.

1 57. The catheter of claim 53, wherein the inwardly spiraling portion does
2 not cross the first plane.

1 58. The catheter of claim 53, wherein the inwardly spiraling portion
2 comprises a portion that is parallel to the uncurled section and lies on the first plane.

1 59. The catheter of claim 53, wherein the inwardly spiraling portion
2 crosses the first plane.

1 60. The catheter of claim 52, wherein the one or more openings comprise a
2 plurality of openings in a sidewall of the catheter.

1 61. The catheter of claim 60, wherein the inwardly spiraling portion
2 comprises an inner periphery that defines an area of open space inside the inner periphery
3 and the openings face into the open space.

1 62. The catheter of claim 61, wherein the one or more openings comprises
2 at least one opening at a distal end of the catheter positioned inside the open space.

1 63. The catheter of claim 52, wherein the inwardly spiraling portion
2 comprises an inner periphery that defines an area of open space inside the inner periphery
3 and the one or more openings comprises at least one opening at a distal end of the catheter
4 positioned inside the open space.

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